Impact of Water Broadening on Atmospheric CO_2 Retrievals for the OCO-2 Mission

F. Oyafuso & Absco team*

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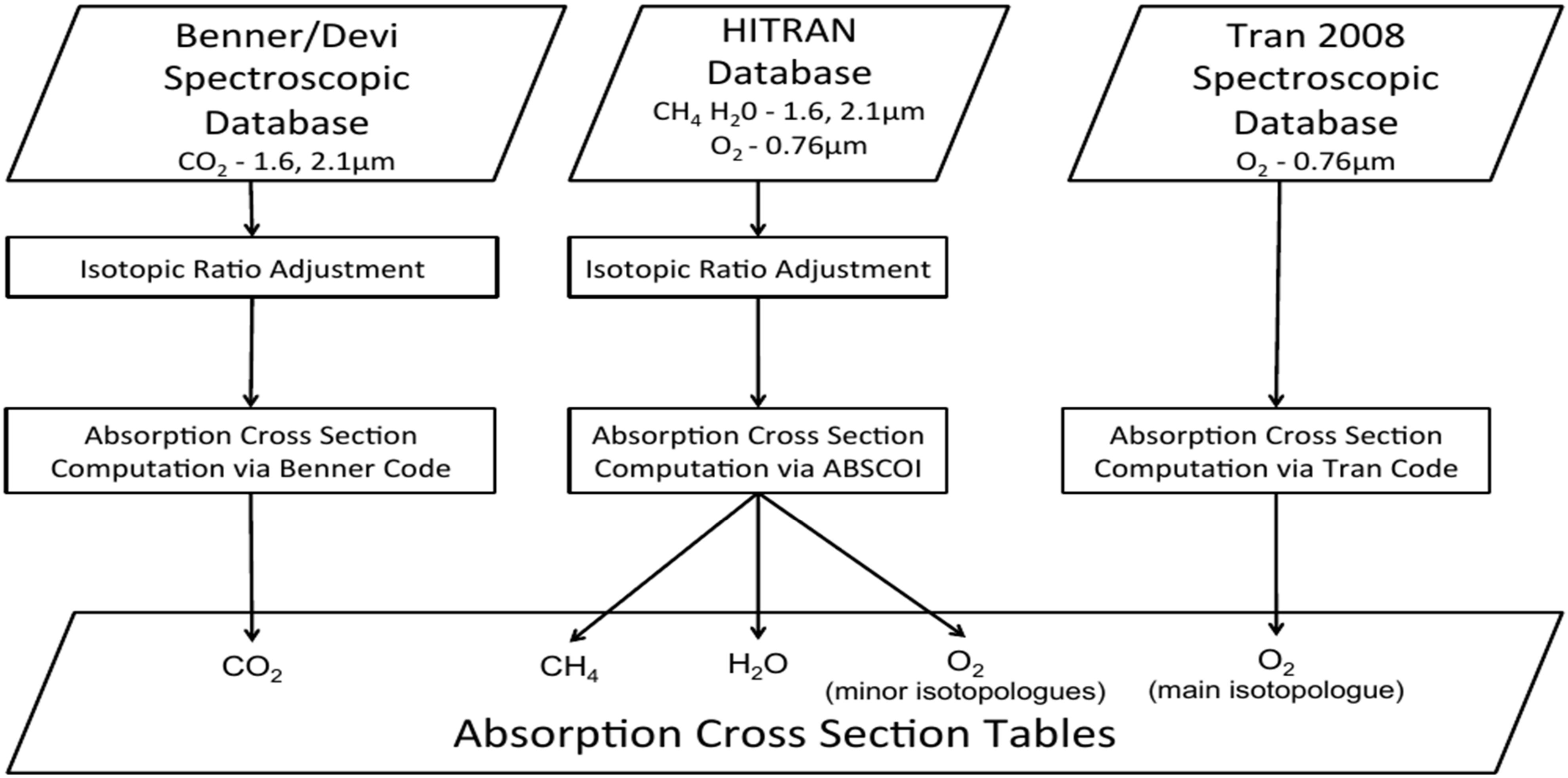
OCO-2 Spectroscopy

OCO precision requirements:

- Goal: 1 ppm (~0.3%)
- Necessitates extreme precision in spectroscopy

Spectroscopy Model:

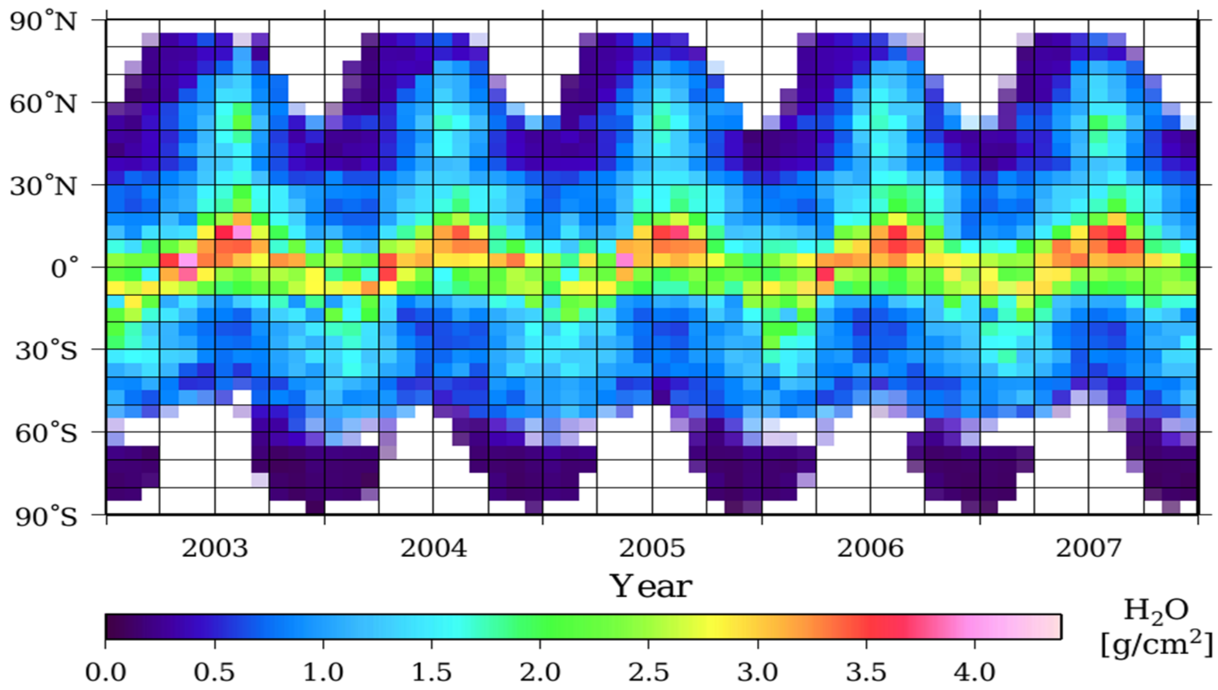
- 3 bands: WCO_2 (1.6μm), SCO_2 (2.06μm), O_2A (0.76μm)



OCO-2 Spectroscopy: Updates

	0.76µm O_2	1.61µm CO_2	2.06µm CO_2	H_2O
Spectral range	12745-13245 cm^{-1}	4700-6500cm^{-1}	4700-6500cm^{-1}	**12745-13245 cm^{-1}** 4700-6500cm^{-1}
Spectral resolution	0.01cm^{-1} or 0.002cm^{-1}	0.01 cm^{-1} or 0.002cm^{-1}	0.01 cm^{-1} or 0.002cm^{-1}	0.01 cm^{-1} or 0.002cm^{-1}
Position	**Long (2010), Long (2011)**	Devi (2007)[1]	Benner/Devi (2011)[1]	**Gordon (2012), Rothman (2010)**
Intensities	"	"	"	"
Air-widths	Tran (2008)	Predoi-Cross (2009)[1]	"	"
Air-shifts	Brown (2009) Robichaud (2008a) Predoi-Cross (2008)	Devi (2007b)[1]	"	"
Temp. dep.	Brown (2000)[1,2]	Predoi-Cross (2009)[1]	"	"
Line shapes	Voigt / **Galatry**	Speed-dependent Voigt	Speed-dependent Voigt	Voigt
Isotopologue abundance	Rothman (2009)[1]	Rothman (2009)	**Rothman (2009)***	Rothman (2009)
H_2O broadening	Vess (2012)/Fanjoux (2012)	Sung (2009)	Sung (2009)	-
Air-Line mixing	Tran (2008)	"	Benner/Devi (2011)	-
" Temp. dep.	Tran (2008)	-	-	-
Speed dep.	-	Devi (2007)[1]	Benner/Devi (2011)[1]	-
Continuum	CIA via Tran (2008)	-	**Mlawer (2011) ***	**Mlawer (2011) ***

Why worry about H_2O?



- Water vapor varies greatly both spatially and temporally.
- Spectroscopic errors associated with water vapor can potentially introduce unphysical biases in retrieved X_{CO2}.
- Effect of water on spectroscopy:
  - Direct absorption
  - Enhanced broadening of CO_2 and O_2.

* H. Schrijver et al., *Atmos. Meas. Tech.*, **2**, 561 (2009)

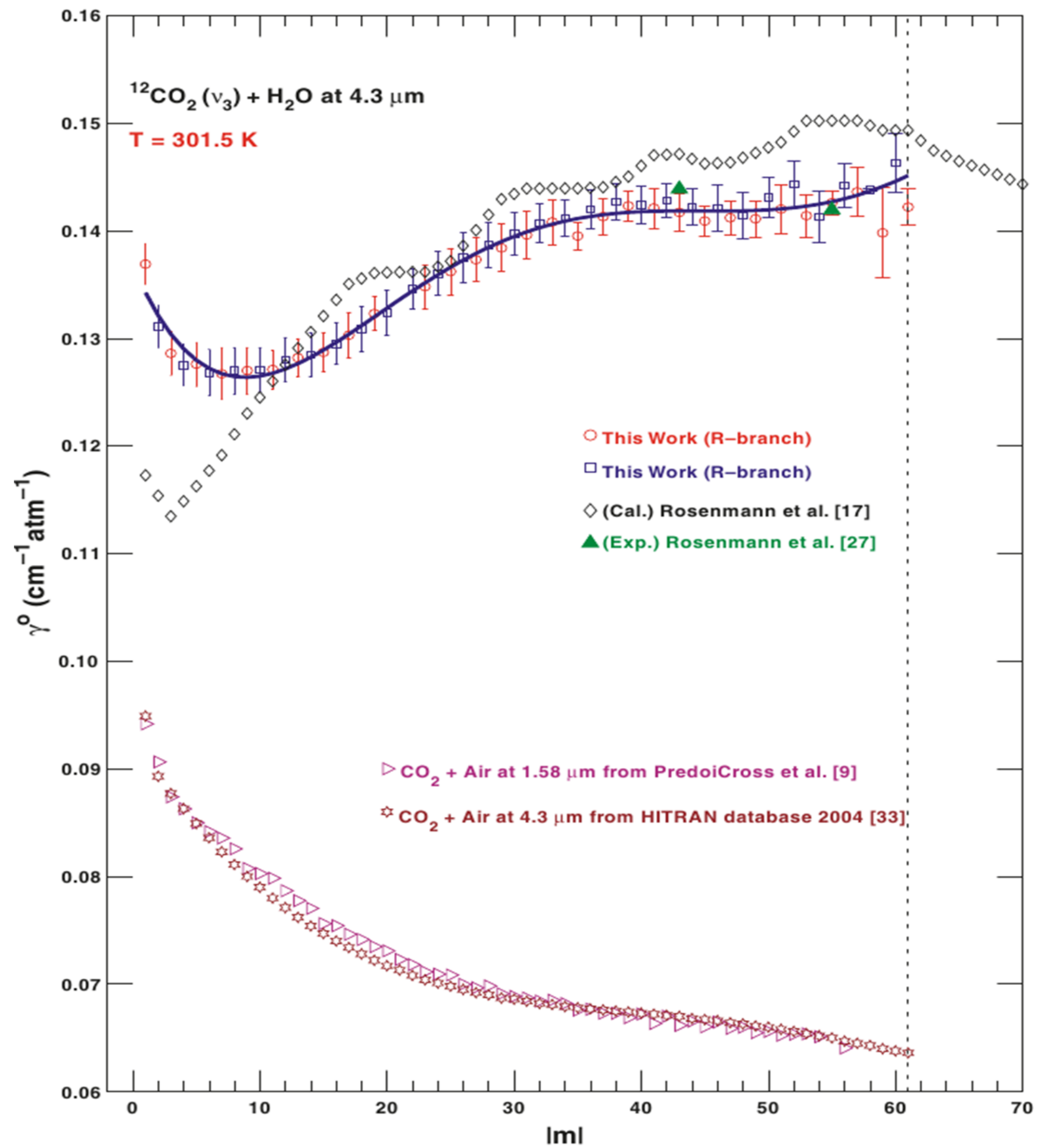
CO_2-H_2O broadening

- Two recent publications:
  - Sung @ 4.3μm
  - Wallace @ 1.6μm (3 lines)

	Sung et al. (4.3 μm)	Wallace et al. (1.6 μm)
R14	0.1287 (1.4 %)	0.136 (19.8 %)
R16	0.1303 (1.6 %)	0.134 (17.9 %)
R18	0.1323 (1.2 %)	0.133 (20.3 %)

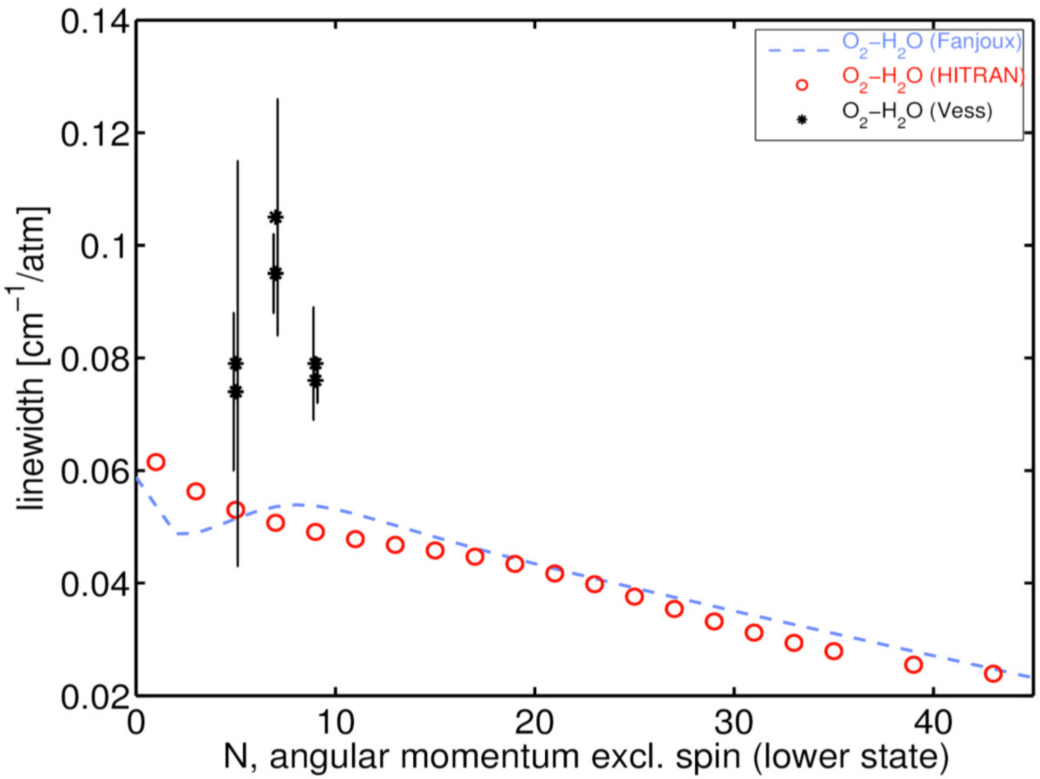
- Weak dependence on vibrational quantum number extends applicability to WCO_2 and SCO_2 bands.
- Use a rational function fit to measured water-broadened CO_2 lines, $\gamma_{CO2 \leftarrow H2O}(J'')$.*

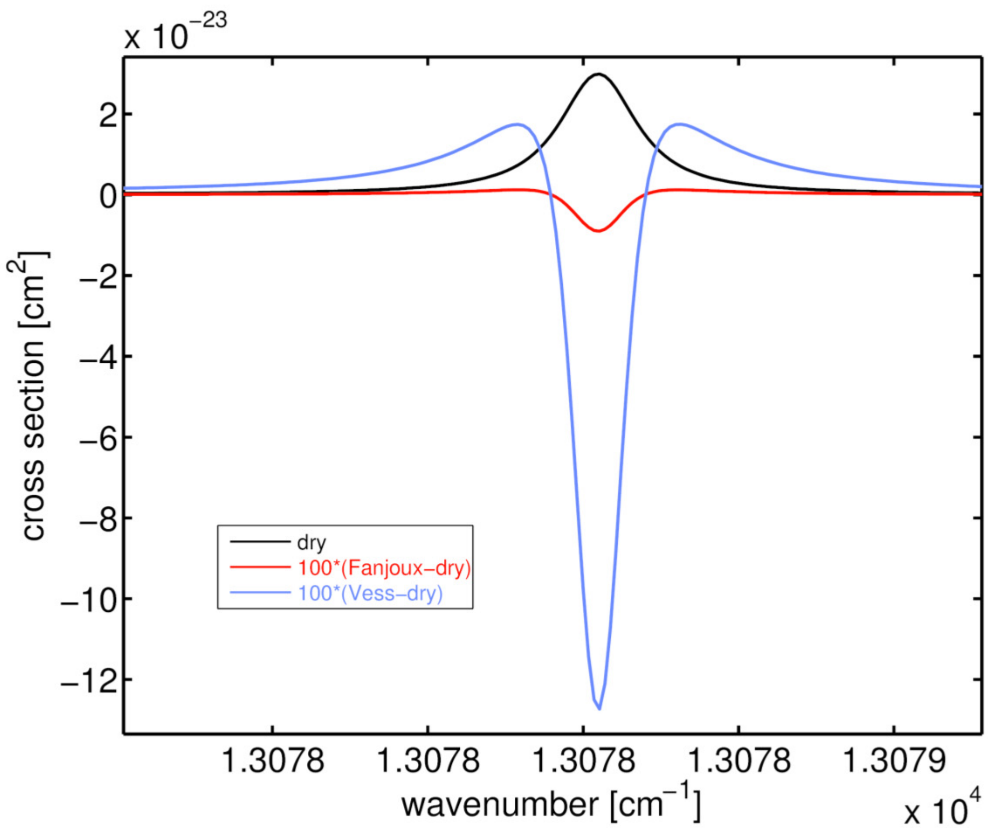
  $\gamma = \gamma_{air} + (\gamma_{self}-\gamma_{air})x_{CO2}$
- Water turns out to be a much more effective broadener for CO_2 than air (~1.8x).



* K Sung, L. Brown, RA Toth, TJ Crawford, *Can J. Phys*, **87**, 469-484 (2009)

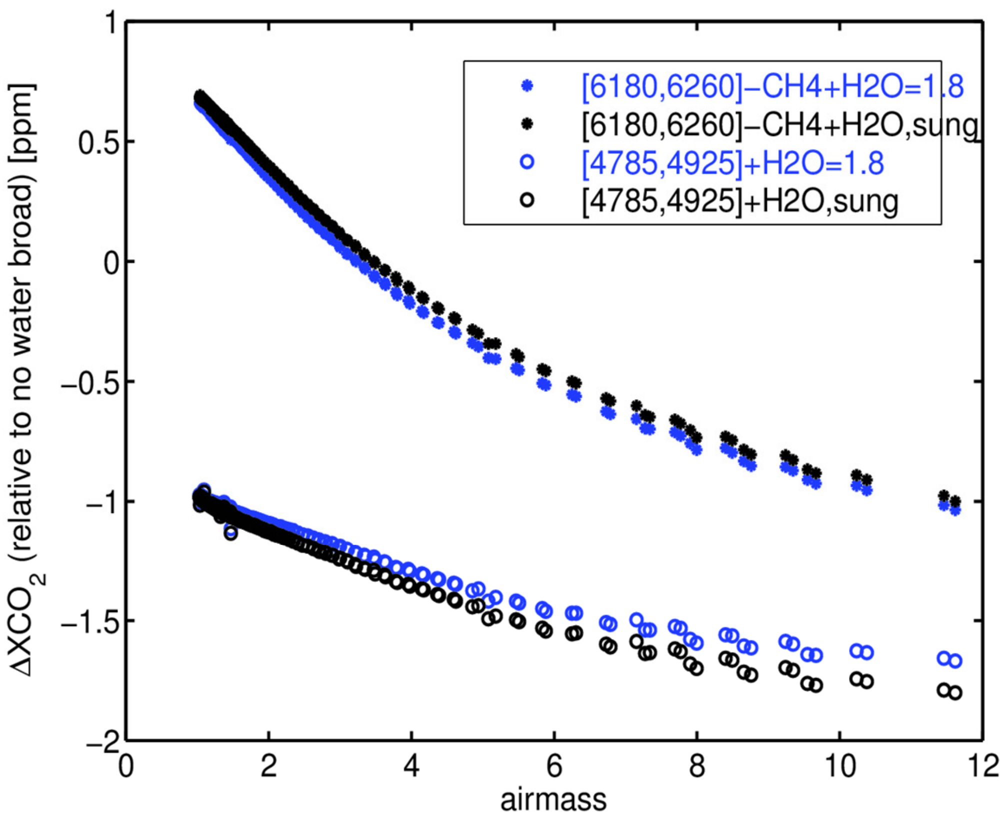
O_2-H_2O broadening: two models

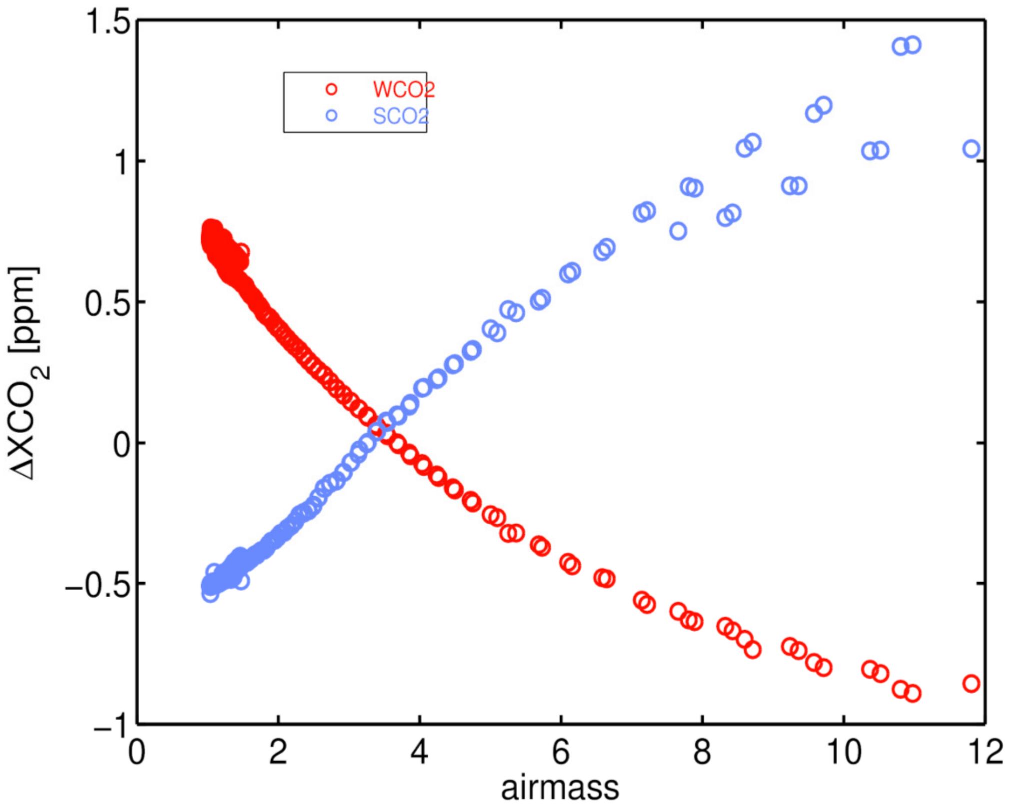




- Until recently, there had been only one publication on H_2O broadening of O_2 (Fanjoux et al, *J. Phys Chem*, **101**, 1061 (1994)). BUT measurements were at high temps 446<T<990K.
- This year another result has been published showing a much greater difference from air (Vess et al, *J. Phys Chem*, **116**, 4069 (2012)), but only six transitions were measured.
- Enhancements differ considerably: ~8% (Fanjoux), ~80% (Vess)

Effect on single band retrievals



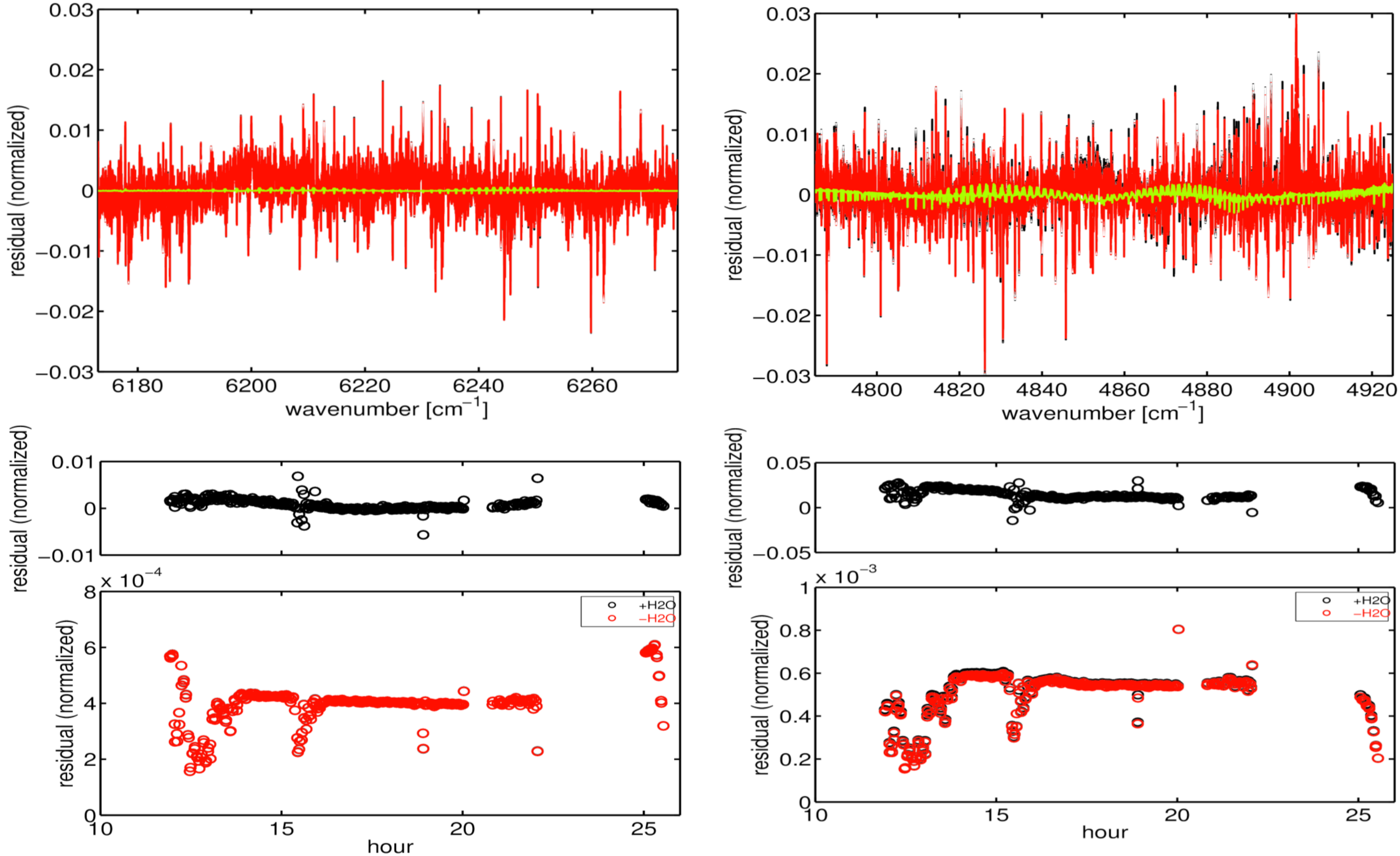


Previously:

- WCO_2 and low optical thicknesses → core reduction *increases* retrieved X_{CO2}.
- SCO_2 → lines are too saturated for cores to matter, enhance of wings *decreases* retrieved X_{CO2}.

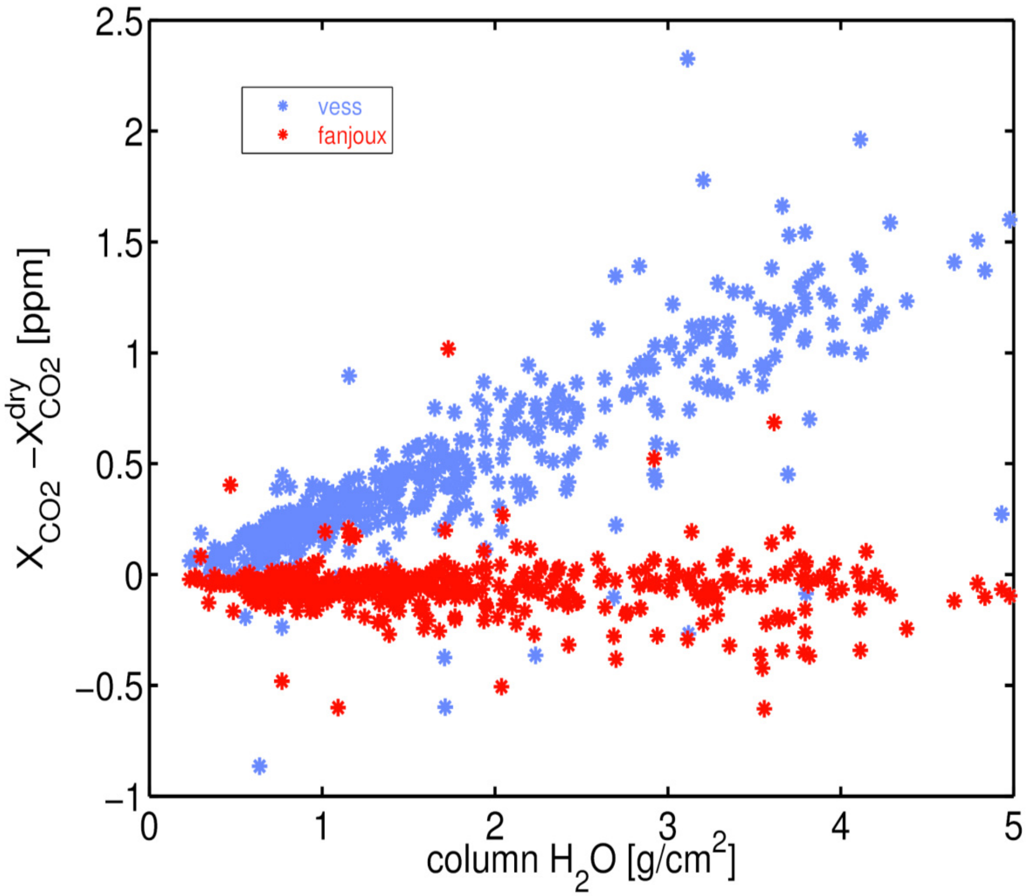
- Addition of water continuum in SCO2 changes things.
- WCO2, SCO2 now largely cancel.

H_2O-CO_2: residuals



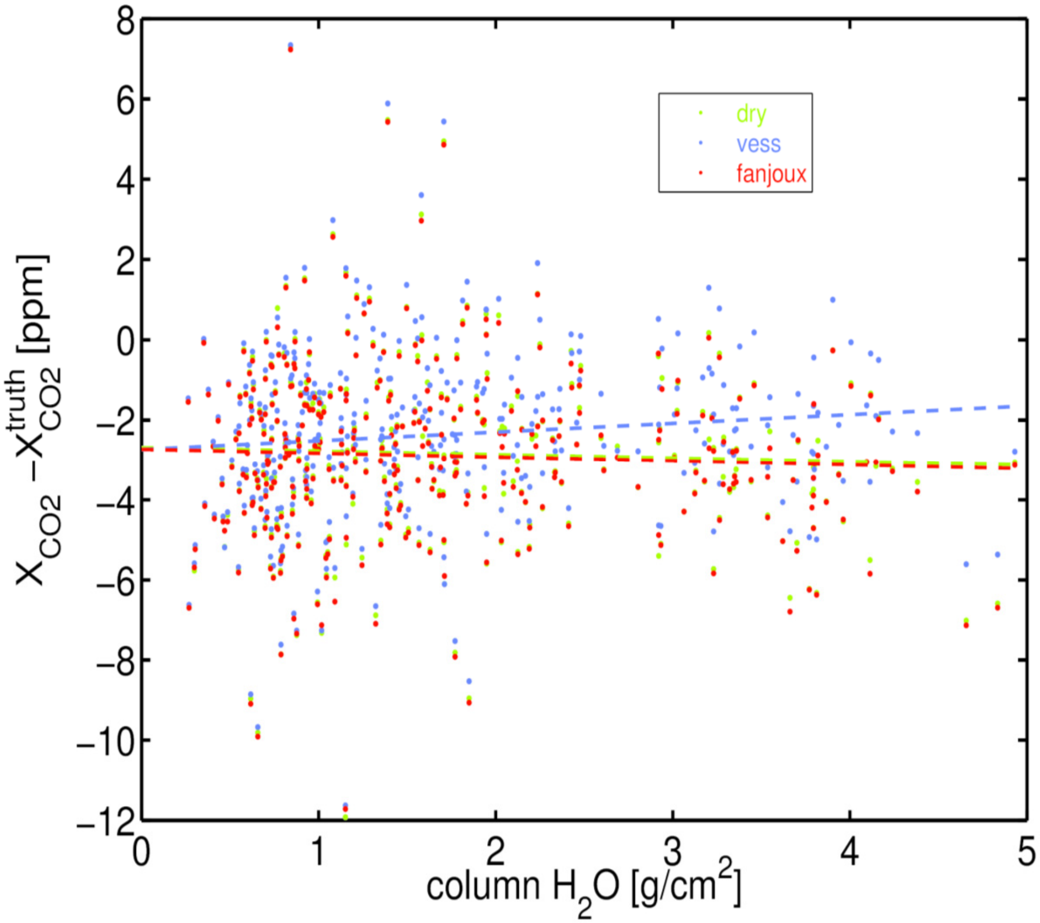
- Residuals are not improved for single band XCO2 retrievals – they worsen slightly.

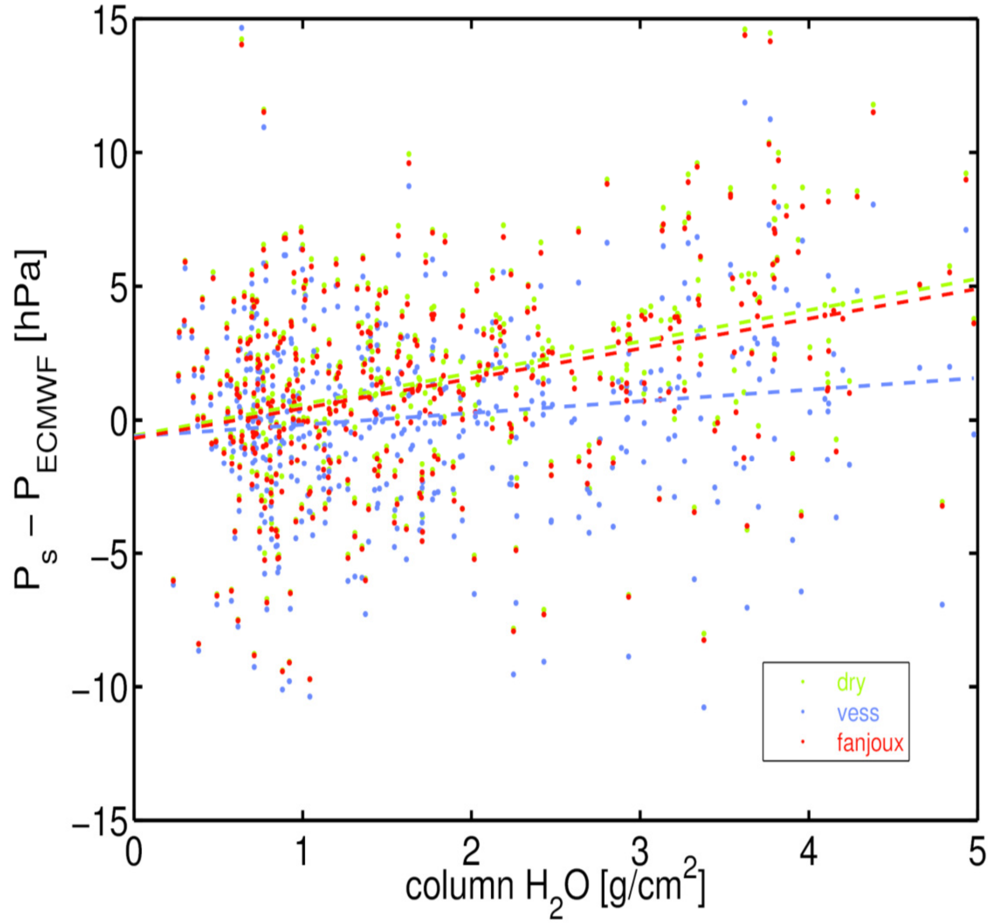
TCCON-coincident GOSAT: XCO_2



- 3 band retrieval complicates analysis:
  - Previous slides show WCO_2, SCO_2 may cancel.
  - Fanjoux O_2-H_2O broadening enhancement is small → little dependence on H2O column
  - If 1.8x approximation (Vess) is valid, XCO_2 spectroscopic error can exceed 1ppm.

TCCON-coincident GOSAT: P_{surf}





- Apart from isotopic abundnces, no additional scaling used:
  - Retrieved surface pressure agrees well with ECMWF:
  - 1.8x enhancement of dry air broadening reduces bias in retrieved surface pressure.
  - However, ~2.5ppm bias exists in XCO2
  - Dependence on water column: -0.09 ppm/(g/cm^2) → +0.22 ppm/(g/cm^2)

Summary

- Capability of modeling water dependent cross sections has been included in the L2 algorithm for OCO-2
- Characterization of H2O-broadened O2 is very uncertain, ...
- … but, if not accounted for, could introduce spatial or temporal biases exceeding the OCO-2 error budget.
- Further lab measurement may be needed to settle the issue.

Acknowledgements

Research described in this talk was performed at Jet Propulsion Laboratory, California Institute of Technology, and was supported by the OCO-2 mission under the National Aeronautics and Space Administration.